STREAM WATER QUALITY REPORT NO. 1
RELATIONSHIP BETWEEN 2001-2002 MONITORING DATA AND HAWAII STATE WATER QUALITY STANDARDS

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Introduction

In this report we compare results of the first two years of stream monitoring work conducted by the Hawaii State Department of Health, Clean Water Branch (HIDOH/CWB), Monitoring Section staff, to the State water quality standards for streams, compiled in the Hawaii Administrative Rules, Chapter 11-54, Water Quality Standards (WQS). Starting in early 2003, this report will be revised after the end of each Hawaii WQS water year (November 1 to October 31) in order to fully describe both wet and dry seasonal conditions encountered in the previous 12 months. These annual reports will be used to develop new information on stream water quality (WQ) as data become available, to track monitoring program progress, and to identify problem areas for attention. These reports may also be included as chapters in the biennial Clean Water Act (CWA) §305 (b) report on the state of the State's waters.

Data Collection Methods

Water samples were collected from streams statewide by HIDOH/CWB Monitoring Section staff and analyzed at the State Laboratory for the following parameters – Total Dissolved Nitrogen (TDN, 2001); Total Nitrogen (TN, 2002), (nitrate+nitrite)-N, ammonium-N, Total Dissolved Phosphorus (TDP, 2001), Total Phosphorus (TP, 2002) and Total Suspended Solids TSS). Turbidity was measured in the field, using Hach turbidity meters at each sampling location.

Water samples and turbidity measurements were taken at upper sites located within or close to the boundary of the upper conservation district lands, where development is prohibited because of steep slopes and use as potable water recharge areas, and at lower sites located downgradient of most development but above the reach of tidally-influenced waters. All measurements were performed on stream waters of less than 0.5 ppt salinity, and compared to the State criteria for streams [HAR 11-54-5.2(b)(1)]. The sampling effort at both upper and lower stations was distributed throughout both "wet" (November-April) and "dry" (May-October) seasons, as identified in HAR 11-54-5.2(b)(1).

Water samples were collected between the dates shown in Table I and analytical results entered into Excel spreadsheets. These data, provided to EPO by the CWB, were reformatted, then exported into Statistica 6 for computation of data summaries and preparation of graphs.

The "no. of site visits" column (Table I) shows the total number of visits recorded in the spreadsheets; the number of visits which resulted in valid samples providing data for analysis is shown in Table II, column 1, "Valid Sample Size." Of the total streams visited, twenty were sampled in both 2001 and 2002 for a total of 118 independent streams in the data set. Streams sampled include CWA 303(d)-listed streams, streams lacking sufficient monitoring data to support a listing decision, and unimpaired streams. The total number of perennial streams in Hawaii is reported as 376 (Hawaii Stream Assessment, 1990); unvisited streams total 376-118 = 258, to be sampled in subsequent years. Statistical analyses reported here were conducted at the level of populations of streams by island and by State.

As of October, 2002, Hawaii's draft CWA 303(d) List of Polluted Waters includes 8 known impaired perennial streams on Kauai, 25 on Oahu, 9 on Maui, and 10 on Hawaii. The List must be updated again by April 1, 2004.

Analytical Methods

1. Data files provided by the CWB were reorganized by major island (Kauai, Oahu, Maui and Hawaii), then sorted within islands by upper stations/wet season, upper stations/dry season and by lower stations/wet season, lower stations/dry season. In accordance with the CWA 303(d) Listing and Delisting Criteria (May, 2002), geometric means were computed only for sample sizes of ten or greater; no "10 % or 2% of the time" values were computed for this report (Table II). Because TDN and TDP were measured in 2001, and TN and TP in 2002, data summaries were separately computed for each calendar year (Table II). The Hach turbidity data, which were field-collected and thus not subject to variations in laboratory procedures, were combined for calendar years 2001-2002 (Table II).

2. After reorganizing the data sets, each sample geometric mean was computed, then divided by the wet season or dry season water quality criterion for that parameter. If the resulting value was less than 1, concentrations of that material in the water met the WQS; if the value was greater than 1, the WQS was exceeded for that parameter. Normalizing the geometric means to the WQS allows data to be displayed in dimensionless form on a scale of 0 – 5 or greater, depending on the extent to which the sample geometric means exceeded the corresponding WQS, and displayed on the same graph using a single vertical scale (Figures 1, 2).

3. Note that, unlike the CWA 303(d) Listing methodology, stream data were aggregated by island, then sorted by wet and dry season collection dates and by upper and lower station locations; results represent population averages, not characteristics of individual streams.

Results and Conclusions

1. Compliance of sample geometric means with the corresponding WQS is reviewed at three levels of data aggregation – individual streams, streams grouped by island, and streams grouped at the State level.

   (a) Data aggregated by individual streams: Data are analyzed at the level of individual streams for purposes of preparing the biennial CWA 303(d) List of Impaired Waters and TMDL reports, and when permits include monitoring requirements. In order to accommodate environmental variability, sampling plans for a stream system should include at least upper and lower stations sampled across both wet and dry seasons. Data from individual streams are not presented in this report; please see HIDOH's 2002 List of Impaired Waters in Hawaii Prepared Under Clean Water Act §303(d) (October, 2002) for a description of analytical methods for data from single streams.

   In general, sparsely-sampled individual streams with small data sets biased toward a particular station or season should not be used to evaluate the adequacy of the WQS. Please follow the data aggregation procedures described in b and c, below, to evaluate adequacy of State WQS as benchmarks for Statewide water quality management, and note that temporal and spatial scaling effects must be taken into account when comparing data sets with the WQS.

   (b) Streams aggregated by island. Aggregating stream data by island increases sample sizes and smoothes out many of the highly site-and-weather specific variations found in smaller data sets from individual streams. At this level of analysis we see that the population of streams on Oahu, the island with the largest number of impaired streams, shows exceedances of the WQS primarily for nitrate, total nitrogen, and Hach turbidity. In all cases these exceedances are greater in the dry season than in the wet season (Table II, Figure 1). A similar, but smaller increase in nitrogen-N is also visible in the Kauai data (Figure 1). Instances where dry season exceedances are larger than wet season exceedances may be an artifact resulting from division by the seasonal WQS, as the unnormalized sample geometric means do not show consistent wet season/dry season exceedance differences when compared to the WQS.

   Data sets from Maui and Hawaii are generally in compliance with the WQS when analyzed across both wet and dry seasons. Analysis of data categorized by upper station/wet/dry seasons and by lower station/wet/dry seasons was not carried out for most data sets because of sample sizes less than ten per category (Table II).

(c) Streams aggregated at the State level. When all data are aggregated at the State level, ratios of sample geometric means for each parameter to the corresponding WQS are mostly less than one, indicating compliance, except for nitrate in 2002 (1.056) and Hach turbidity in 2001 - 2002 (1.350) (Table III).

When these ratios are converted to percents, we see that the Statewide geometric means computed for 2001 and 2002 data constitute 10%-11% of the WQS for TSS; 43% to 106% of the WQS for nitrate; 53% to 70% of the WQS for TDN and TN; 31% to 44% of the WQS for TDP and TP; and 135% of the WQS for turbidity (Table III). The magnitude of variation in sample geometric means among islands is shown by the standard error of the mean (Table III).

Data for 2001 and 2002 were analyzed separately because of the switch from TDN and TDP in 2001 to TN and TP in 2002. Although State level geometric means are higher for TN and TP than for TDN and TDP, which might suggest that dissolved nutrient concentrations were lower than total concentrations, which include particulate matter, nitrate concentrations were considerably elevated in 2002 compared to 2001 (the nitrate analysis did not change between 2001 and 2002.) Rainfall amounts across the State were greater in 2002 than in 2001, confounding any conclusions about the consistency of the relative concentrations of dissolved versus total N and P in streamflows over time. We will retain the current TN and TP analyses at least through 2003.

Elevated nitrate and total nitrogen levels, found primarily on Oahu, are likely an indicator of nitrogen pollution, a global problem driven by increasing use of commercial fertilizers, failing or non-existent wastewater collection and treatment systems, and atmospheric deposition of NOx compounds. As population size and land development increase on the Neighbor Islands, nitrogen concentrations measured in surface waters are also likely to increase.

3. When data sets from individual streams are compared to State-level WQS, originally derived from statewide stream data, the question becomes: "Are these data drawn from the same underlying distribution of values in the data set aggregated at the state level?' In practice, it is easiest to compare new data from a stream to previously-collected data sets from the same locations in order to draw conclusions as to whether pollutant concentrations have increased or decreased in a stream system over time. One way to make this comparison is to require that the CWB sampling sites in a stream system be included in future CWB sampling plans for the system, or in sampling plans prepared by TMDL contractors and permit applicants for new locations in a

stream system, in order to provide a basis for both evaluating overall stream WQ compliance with WQS and increasing the size of the data set.

4. As stream data sets increase over time, enough data will be accumulated from minimally-polluted streams to provide a clearer view of "natural background" conditions. However, at present we can be more careful to ask, when we hear the statement "the WQS are exceeded all over the place," – What are the locations where data support this statement? What are the sample sizes? What is the extent of temporal and spatial coverage of the sampling effort? If investigators sample only sites in streams receiving pollutants from adjacent urban, residential, and agricultural activities with no BMPs or vegetated buffer strips in place, the WQS will be exceeded compared to background conditions (these are the impaired streams). This type of sampling plan does not allow evaluation of the WQS themselves.

5. As a long-term goal, the preferred data set should contain a minimum sample size of ten for each of the following conditions – upper station, wet season, upper station, dry season; lower station, wet season, lower station, dry season – resulting in a total of 40 data points per stream. The metadata should include records of visits when stream beds were dry, or instances where access to an upper station is truly not possible (not simply inconvenient). Data collected under NPDES permits or CWA 401 Water Quality Certifications should be linked to CWB monitoring stations and to other WQ data for that stream in order to utilize all available data to support conclusions on overall water quality of a stream reach or stream system.

   Although it will take several years to accumulate enough data to meet the minimum sample size of ten per location and season, this effort is necessary to support improvements in our ability to make sound decisions on water quality impairment and non-impairment, as judged with respect to the WQS. Stream data sets collected to date represent a good start, but the present ten samples per entire stream system should be increased to 40 to improve the time-and-space coverage needed to evaluate WQ against the stream WQS. Sampling requirements may be reduced in the future when sufficient data are available to support development of loading algorithms for various land uses and topographies, and to support time-trend analyses of data collected from reference streams.

   Right now, WQ impairment levels appear to vary with development density per island and with commercial fertilizer use and wastewater system failures; exceedances of the ratios of sample geometric means to the WQS are likely to increase over time if land use practices are not modified in the direction of pollution abatement. Over time, these appearances must be studied with increasingly more rigorous watershed analysis methods than those presently applied. The TMDL studies provide the analytical framework for impaired streams; the TMDL methodology can be modified to better identify potential sources of impairment on streams presently meeting WQS. Factors to consider in the development of future sampling plans include at least topography, land use, and climate.

In conclusion, the key to determining whether the WQS correctly express concentrations of specific substances in minimally polluted streams, or to evaluating water quality in any stream, is…MEETING MINIMUM REQUIREMENTS FOR SAMPLE SIZE AND NUMBER OF STATIONS, AND ASSEMBLING ADEQUATE INFORMATION IN A GIS DATABASE TO ESTIMATE NATURAL BACKGROUND AND HUMAN INFLUENCES ON WATER QUALITY AT BOTH SPECIFIED SAMPLING LOCATIONS AND ACROSS THE STATE.

TABLE I. Data collection effort by island.

YEAR	**ISLAND**	**NO. OF SITE VISITS**	**NO. OF STREAMS SAMPLED**	**COLLECTION INTERVAL**
2001	Kauai	37	18	Jan 22 – Dec 18
	Oahu	89	31	Nov 1, 2000 – Nov 19
	Maui	57	25	Dec 4, 2000 – Sept 24
	Hawaii	63	23	Jan 8 – Dec 3
2002	Kauai	38	6	Mar 19 – July 22
	Oahu	17	7	Jan 22 – July 28
	Maui	24	21	Apr 15 – July 22
	Hawaii	34	7	Feb 4 – June 3
2001 & 2002 (Hach Turbidity in field)				
	Kauai	409	Same streams sampled as above	Nov 29, 2000 – Aug 6, 2002
	Oahu	407		Nov 1, 2000 – July 30, 2002
	Maui	391		Feb 1, 2000 – Aug 6, 2002
	Hawaii	169		Nov 24, 2000 – June 17, 2002

TABLE II. Geometric means for each sample data set divided by the corresponding water quality criterion for that parameter. Values >1 show islands, station locations, and wet/dry seasonal conditions under which the water quality standards for streams (HAR 11-54-0?) are exceeded. Minimum sample for analysis = 10. TSS, NO3, TDN/TN, TDP/TP were measured in the State Lab; turbidity was measured in the field with a Hach instrument. TDN and TDP were measured in 2001; TN and TP were measured in 2002. 2001 data were obtained during the period 11/01/00 – 12/18.01; 2002 data span the period 01/22/02 – 17/28/02. Values greater than 1. are shown in ***bold italics***.

	Valid Sample Size	**TSS meang/WQS**	**NO3 meang/WQS**	**TDN/TN meang/WQS**	**TDP/TP meang/WQS**	**Hach Turb meang/WQS (2001-2 combined)**
KAUAI (2001)						
Wet (all)	33	0.0621	0.386	0.372	0.300	-----
Dry (all)	4	-----	-----	-----	-----	-----
Upper						
Wet	15	0.644	0.09888	0.230	0.134	-----
Dry	2	-----	-----	-----	-----	-----
Lower						-----
Wet	18	0.552	0.217	0.348	0.134	
Dry	2	-----	-----	-----	-----	-----
KAUAI (2002)						
Wet (all)	3	-----	-----	-----	-----	-----
Dry (all)	20	0.167	***2.11***	0.723	0.437	-----
Upper						
Wet	2	-----	-----	-----	-----	0.859 (n=40)
Dry	20	0.229	0.824	0.655	0.216	***2.23*** (n=23)
Lower						
Wet	4	-----	-----	-----	-----	0.730 (n=52)
Dry	20	0.326	***1.76***	***1.18***	0.486	***2.88*** (n=26)

TABLE II. (continued)

	Valid Sample Size	**TSS meang/WQS**	**NO3 meang/WQS**	**TDN/TN meang/WQS**	**TDP/TP meang/WQS**	**Hach Turb meang/WQS (2001-2 combined)**
OAHU (2001)						
Wet (all)	45	0.114	0.873	0.780	0.354	
Dry (all)	39	0.260	***2.32***	***1.00***	0.640	
Upper						
Wet	14	0.156	***1.27***	***1.10***	0.428	
Dry	14	0.226	***3.45***	***1.12***	0.593	
Lower						
Wet	28	0.132	***1.37***	0.942	0.390	
Dry	30	0.291	***2.30***	***1.20***	0.698	
OAHU (2002)						
Wet (all)	15	0.0587	***1.14***	0.594	0.298	
Dry (all)	23	0.216	***2.17***	***1.03***	0.853	
Upper						
Wet	4	-----	-----	-----	-----	***1.02*** (n=31)
Dry	2	-----	-----	-----	-----	***1.26*** (n=28)
Lower						
Wet	11	0.0707	***1.51***	0.747	0.311	***1.52*** (n=69)
Dry	20	0.229	***2.54***	***1.15***	0.839	***1.92*** (n=91)

TABLE II (continued).

	Valid Sample Size	**TSS meang/WQS**	**NO3 meang/WQS**	**TDN/TN meang/WQS**	**TDP/TP meang/WQS**	**Hach Turb meang/WQS (2001-2 combined)**
MAUI (2001)						
Wet (all)	19	0.065	0.106	0.337	0.224	
Dry (all)	12	0.118	0.407	0.457	0.433	
Upper						
Wet	8	-----	-----	-----	-----	
Dry	6	-----	-----	-----	-----	
Lower						
Wet	11	0.0998	0.489	0.322	0.177	
Dry	6	-----	-----	-----	-----	
MAUI (2002)						
Wet (all)	25	0.0508	0.443	0.392	0.260	
Dry (all)	8	-----	-----	-----	-----	
Upper						
Wet	4	-----	-----	-----	-----	***1.02*** (n=31)
Dry	4	-----	-----	-----	-----	***1.18*** (n=28)
Lower						
Wet	21	0.0582	0.3939	0.3559	0.2521	***1.43*** (n=69)
Dry	4	-----	-----	-----	-----	***4.51*** (n=91)

TABLE II. (continued)

	Valid Sample Size	TSS meang/WQS	NO3 meang/WQS	TDN/TN meang/WQS	TDP/TP meang/WQS	Hach Turb meang/WQS (2001-2 combined)
HAWAII (2001)						
Wet (all)	34	0.114	0.873	0.780	1.74	
Dry (all)	20	0.260	***2.323***	***1.00***	3.60	
Upper						
Wet	17	0.0528	0.132	0.347	0.186	
Dry	11	0.122	0.374	0.572	0.288	
Lower						
Wet	17	0.0631	0.263	0.517	0.208	
Dry	9	-----	-----	-----	-----	
HAWAII (2002)						
Wet (all)	5	-----	-----	-----	-----	
Dry (all)	12	0.148	0.567	0.989	0.333	
Upper						
Wet	3	-----	-----	-----	-----	0.724 (n=66)
Dry	6	-----	-----	-----	-----	***1.49*** (n=44)
Lower						
Wet	2	-----	-----	-----	-----	0.744 (n=43)
Dry	6	-----	-----	-----	-----	***1.29*** (n=45)

TABLE III. Mean ratios across islands for each water quality parameter ± standard error of the mean

	TSS 2001	TSS 2002	NO3 2001	NO3 2002	TDN 2001	TN 2002	TDP 2001	TP 2002	Hach Turb 2001-2002
+ Standard error	0.1249	0.1470	0.6266	***1.466***	0.6230	0.8305	0.3660	0.5445	***2.253***
Statewide geometric mean	0.1017	0.1098	0.4300	***1.056***	0.5339	0.7024	0.3117	0.4362	***1.350***
- Standard error	0.08283	0.08193	0.2951	0.7612	0.4575	0.5881	0.2655	0.3279	0.8085

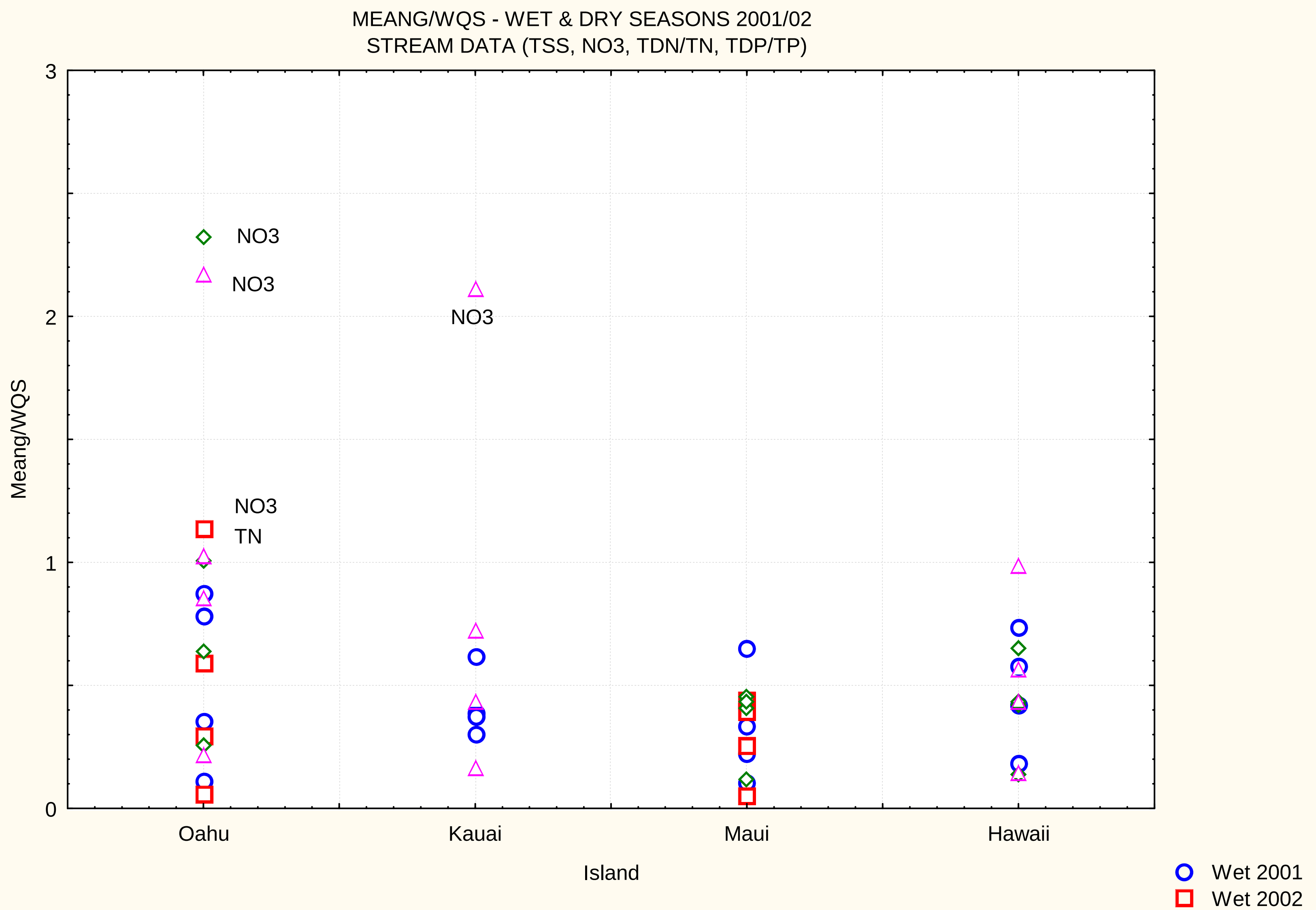

Figure 1. Relationship between ratios of geometric means for TSS, NO3, TN and TP to corresponding water quality standards. Values > 1 (labelled) identify those parameters with means exceeding the WQS for nitrate and total nitrogen in dry and wet season data sets collected in 2001 and 2002.

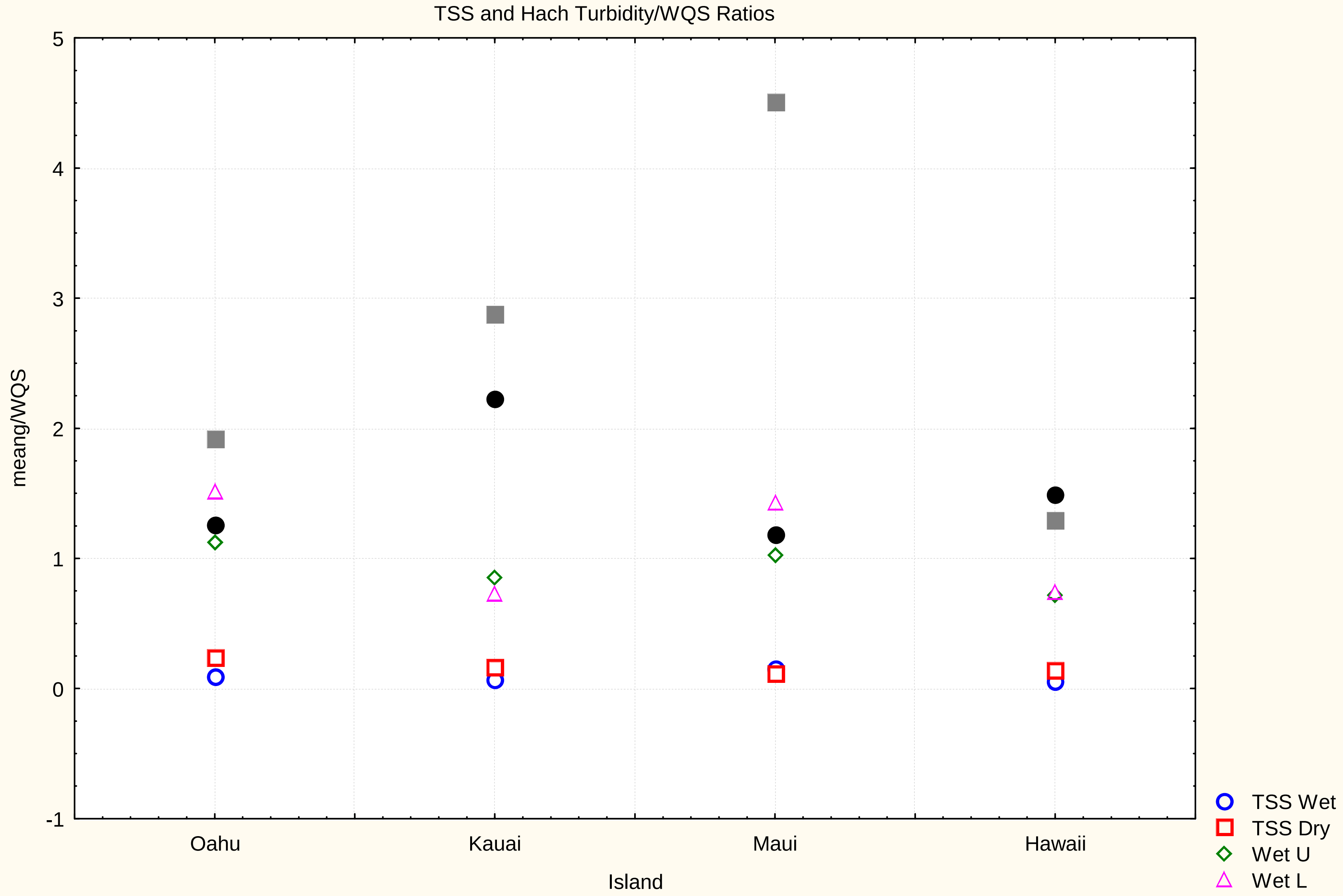

Figure 2. Relationship between ratios of geometric means for TSS and Hach turbidity to corresponding water quality standards. Values > 1 identify those parameters with means exceeding the WQS in 2001 and 2002.